

Demonstration and Pilot-Scale Testing of
Furnace Sorbent Injection for SO₂
Control on Tangentially Coal-Fired Boilers

Combustion Engineering, Inc., Windsor, CT

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ABSTRACT

Combustion Engineering, under EPA sponsorship, has initiated a program to demonstrate furnace sorbent injection on a tangentially fired, coal-burning utility boiler. The overall objective of the program is to demonstrate significant reductions in SO₂ and NO_x while minimizing any negative impacts on boiler performance.

The demonstration program follows a recently completed laboratory program, also under EPA sponsorship, to develop sorbent injection criteria for controlling SO₂ from tangentially fired coal boilers. The earlier program established procedures for optimizing the design and performance of a sorbent injection system via aerodynamic flow modeling and pilot-scale combustion testing.

The demonstration program, which draws heavily upon the procedures established under the earlier program, also includes unit-specific aerodynamic flow modeling and pilot-scale combustion testing to identify and verify optimum sorbent injection and NO_x reduction approaches. The program will culminate with an 8-month demonstration test at Virginia Power's 180 MW(e) Yorktown Unit No. 2. Flue gas humidification and low temperature simulated sorbent recycle for enhanced SO₂ removal will also be demonstrated during the 8-month test.

The overall demonstration program organization and schedule, plus the results of pilot-scale testing under the earlier program, are discussed in the paper.

INTRODUCTION

Furnace sorbent injection is under development as an approach for SO₂ control for coal-burning utility boilers. The process is attractive for retrofit of existing boilers since the capital equipment requirements and overall sulfur reduction costs per ton of sulfur removed are less than for other options such as flue gas desulfurization (Clark et al., 1986). In the furnace sorbent injection process, sorbent, usually calcium hydroxide (Ca(OH)₂) or limestone (CaCO₃), is inject-

ed above the flame zone and mixes with the combustion products containing sulfur dioxide (SO₂). The SO₂ reacts chemically with lime (CaO), formed from the sorbent, to make solid calcium sulfate (CaSO₄). The CaSO₄ is removed with flyash in particulate collection equipment.

A significant fraction of the existing boilers in the United States that would be candidates for retrofit with sorbent injection technology are tangentially fired units. Tangential firing introduces special considerations for the design of sorbent injection systems due to the unique aerodynamics in the sorbent mixing region of tangentially fired furnaces. The U.S. Environmental Protection Agency (EPA) recognized this fact when it awarded Combustion Engineering a contract for Demonstration of Sorbent Injection Technology on a Tangentially Coal-Fired Utility Boiler (EPA Contract 68-02-4275). This demonstration program, which complements an ongoing sorbent injection demonstration program for wall-fired boilers at Ohio Edison's Edgewater Station, follows the recently completed program for Development of Sorbent Injection Criteria for Sulfur Oxides Control from Tangentially Fired Coal Boilers performed by Combustion Engineering under EPA sponsorship (EPA Contract 68-02-4224). This paper presents an overview of the tangentially fired sorbent injection demonstration program, as well as the results of pilot-scale combustion testing under the earlier Sorbent Injection Criteria Development program.

DISCUSSION

Combustion Engineering (C-E), under EPA sponsorship, has initiated a program to demonstrate furnace sorbent injection on a tangentially fired, coal-burning utility boiler. The overall objective of the program is to demonstrate significant reduction (approximately 50%) in SO₂ and NO_x while minimizing any negative impacts on boiler performance during long-term operation of an integrated sorbent injection system and a low-NO_x firing system. The program will address technical sorbent injection-related problem areas, such as sorbent



Figure 1 Virginia Power's Yorktown Station

handling and injection, precipitator performance, ash handling and disposal, and the possibility of convective pass fouling over a period of operation sufficient to establish cost-effective resolutions.

The program includes aerodynamic flow modeling and pilot-scale combustion testing at C-E's Kreisinger Development Laboratory to identify and verify optimum sorbent injection and NO_x reduction approaches and operating requirements for demonstration testing at Virginia Power's Yorktown Unit No. 2. An aerial view of the Yorktown Power Station, located in Yorktown, Virginia, is shown in Figure 1. Unit No. 2 is to the right of the smaller stack.

Host Unit Description

Yorktown Unit No. 2 is a tangentially fired, Controlled Circulation reheat boiler with a current rating of 180 MWe. A side elevation of Unit No. 2 is shown in Figure 2. Pertinent data describing Unit No. 2 are presented in Table 1. Unit No. 2 features a divided furnace with a water-cooled

TABLE 1

VIRGINIA POWER YORKTOWN UNIT NO. 2

UNIT DESCRIPTION

Type:	Tangentially fired, Controlled Circulation, reheat, divided
Rating:	180 MW maximum capacity; 150 MW rated
Date in Service:	January 1959
Steam Conditions:	2000 psi/1000°F/1000°F (13,790 kPa/538°C/538°C)
Main Steam Flow:	1,200,000 lb/hr (151.2 kg/sec)
Reheat Steam Flow:	1,060,000 lb/hr (133.6 kg/sec)

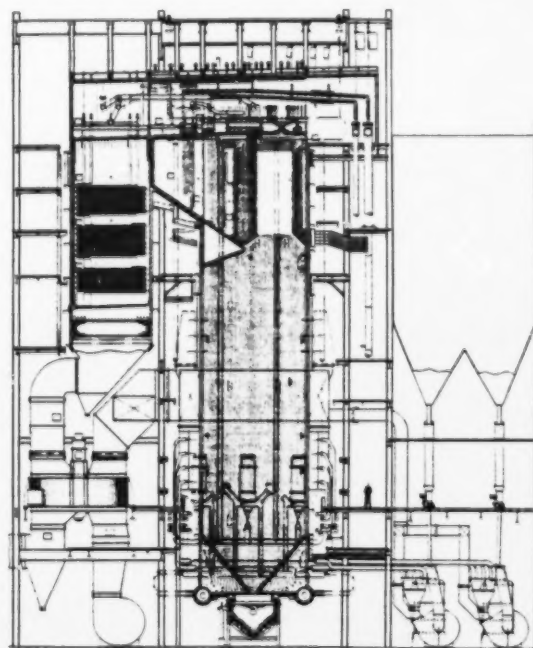


Figure 2 Side Elevation of Virginia Power, Yorktown Unit No. 2

centerwall, with four levels of tilting tangential burners on each side of the dividing wall.

Yorktown Unit No. 2 is equipped with two Ljungstrom regenerative air heaters. Flue gas from these air heaters enters the electrostatic precipitator (ESP) via separate inlet ducts. The ESP, with a specific collection area (SCA) of 720, was installed in 1985. When combined with humidification of the flue gas, this large capacity should permit operational flexibility during the demonstration test. Material collected in the ESP hoppers is pneumatically transported to an ash silo, from which it is trucked to a Virginia Power-owned landfill disposal site 2 miles (3.2 km) away.

Program Description

The demonstration program is divided into six tasks:

- Task 1 Program Management
- Task 2 Development of Preliminary LIMB (Limestone Injection Multistage Burner) Concept
- Task 3 Determination of Baseline Conditions
- Task 4 Conduct of Demonstration Program
- Task 5 Preparation of Recommendations and Guidelines for LIMB Commercialization
- Task 6 Site Restoration

The Program Schedule is shown in Figure 3. Work on the contract started in June 1987 and is scheduled to be completed in November 1992. Baseline testing without sorbent injection is scheduled for late 1989. Demonstration testing is scheduled for 1991. A medium sulfur (2.0 to 2.5% sulfur) eastern bituminous coal will be used. Atmospheric hydrated lime ($\text{Ca}(\text{OH})_2$) will be used as the sorbent.

Each of the tasks is briefly discussed below. The results of pilot-scale testing under the Sorbent Injection Design Criteria contract are also discussed.

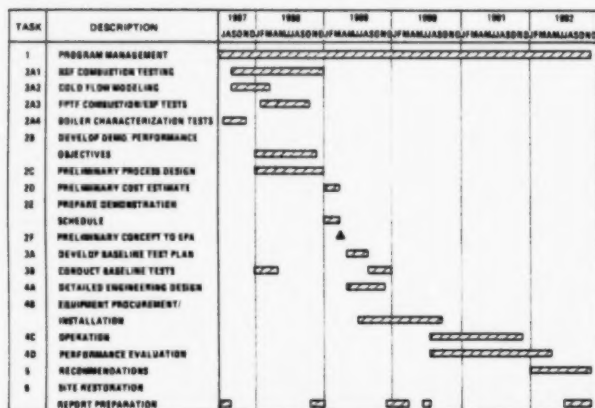


Figure 3 Program Schedule for EPA Tangentially Fired LIMB Demonstration Program

Program Management

In addition to the normal technical and cost management and reporting activities which occur under this task, a separate Technology Monitoring and Transfer subtask has been established under which C-E will interface with the EPA, other govern-

ment and private agencies, and industrial organizations to monitor, evaluate, and incorporate current information related to sorbent injection and other related issues.

This tangentially fired demonstration program is, sequentially, the third full-scale EPA-sponsored sorbent injection program, following the wall-fired demonstration program at Ohio Edison's Edgewater Station and the tangentially fired prototype test program at Richmond (Indiana) Power and Light. Information obtained during these programs, such as ESP performance enhancements, sorbent handling requirements, and waste handling and disposal considerations, will be incorporated into the Yorktown demonstration program.

Development of Preliminary LIMB Concept

The preliminary approach for the sorbent injection system, low- NO_x firing equipment, and flue gas humidification system will be established under this task. In support of this effort, site-specific studies are being conducted, both on-site at Yorktown and off-site at Combustion Engineering's Kreisinger Development Laboratory in Windsor, Connecticut.

On-Site Studies. Extensive temperature traversing was conducted on Yorktown Unit No. 2 at both maximum continuous rating (MCR) and 70% MCR conditions to define temperature profiles and identify the critical temperature zone for sorbent injection. Velocity traversing was conducted to establish furnace flow patterns. This temperature and velocity information was used to establish candidate injection locations for cold-flow and pilot-scale combustion testing.

Off-Site Studies. Under the Development of Sorbent Injection Criteria program, C-E demonstrated that good performance correlations could be obtained between cold-flow and pilot-scale combustion testing. The methods and procedures established under this earlier program are being successfully applied to the off-site studies being conducted in support of the demonstration program. A brief discussion of the activities conducted, and results achieved, under the Sorbent Injection Criteria program follows, after which a brief discussion of the off-site studies under the demonstration program is presented.

Development of Sorbent Injection Criteria Program. The primary objective of this program was to address the criteria for establishing the location and method of injection in tangentially fired coal-burning furnaces in order to provide optimum time/temperature conditions to obtain the most effective removal of sulfur oxides (SO_x). The program included cold-flow isothermal modeling, mathematical modeling, combustion testing, and system design recommendations.

Cold-flow (isothermal) modeling was conducted in the Large Scale Furnace Aerodynamic Test Facility (LSFATF), a 0.46:1 scale model of C-E's 14.7 MW(t) (50×10^6 Btu/hr) Boiler Simulation Facility (BSF). The BSF is shown in Figures 4 and 5. The LSFATF is shown in Figure 6. In this program, techniques were developed for evaluating myriad alternative injection conditions by visually assessing the penetration and dispersion performance of each candidate injection configuration at different velocities and injection angles. Sixteen configurations were tested with flow visualization using smoke through

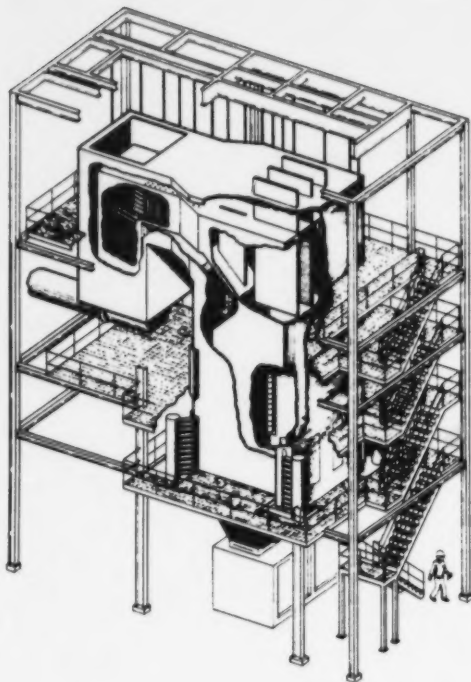


Figure 4 Combustion Engineering's Boiler Simulation Facility (BSF)

the injectors. A typical sorbent injection flow visualization pattern is shown in Figure 7. The best injector configurations were retested using methane tracer gas. Through this approach, the most promising injector configurations were identified for combustion testing at the BSF.

BSF testing was performed using an eastern bituminous coal containing 2.7 to 3.2% sulfur. Over 160 tests were performed, including baseline tests, upper furnace temperature characterization tests,

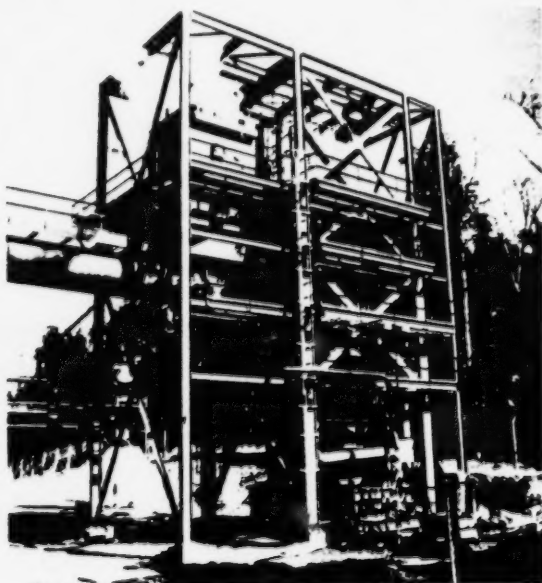


Figure 5 BSF in Operation

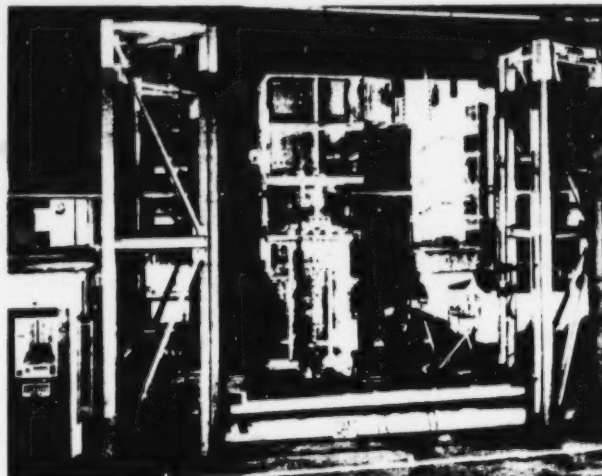


Figure 6 Large Scale Furnace Aerodynamic Test Facility

and NO_x measurements, as well as sorbent injection tests over a range of Ca/S molar ratios, sorbent types, injector tilts, sorbent carrier air velocities, and injector locations. The injector locations which were tested are shown in Figure 8. Three sorbents were tested: untreated Black River hydrated lime, untreated Marblehead hydrated lime,

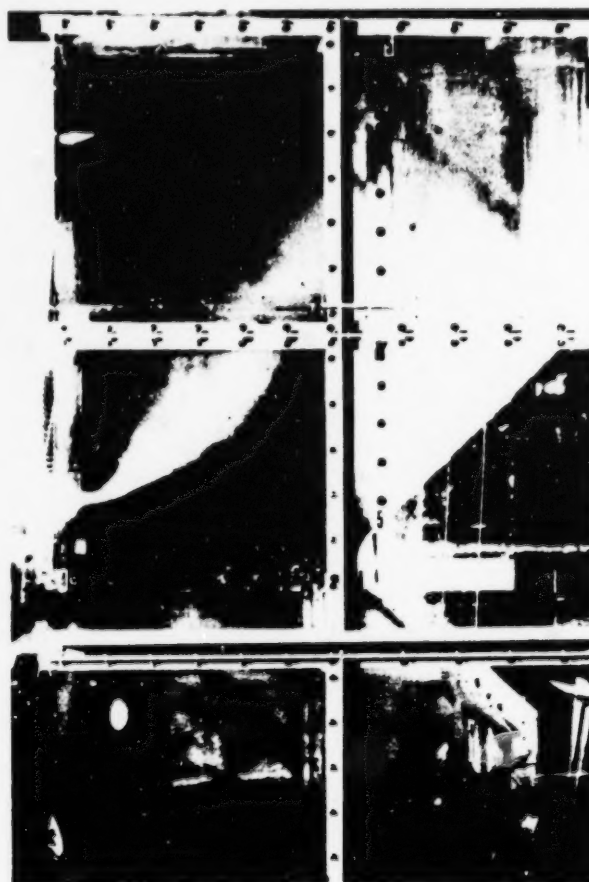


Figure 7 Typical Flow Visualization Test of Front Wall Injection

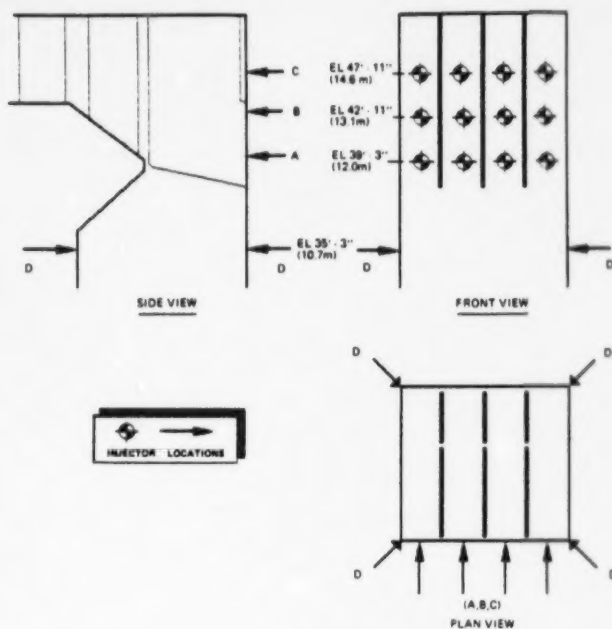


Figure 8 Tested Injector Locations

and Marblehead hydrated lime treated with calcium lignosulfonate. SO_2 capture varied with sorbent type and test conditions.

Up to 50% SO_2 capture was achieved with lignosulfonate-treated hydrate; the other sorbents produced lower SO_2 captures. This is consistent with results achieved by the EPA during bench-scale testing (Kirchgessner and Lorrain, 1987).

Although most sorbent injection tests were run for a constant 20 minute time interval, longer tests showed that SO_2 capture could be increased by 10 to 20% (or 4 to 10 percentage points) by extending the sorbent injection to 1 hour. The increased SO_2 capture was due to deposition of reactive sorbent on heat transfer surfaces. This suggests that commercial operation of the process may require adjustment of sootblowing schedules to allow for controlled buildup of deposits in order to maximize SO_2 capture.

Demonstration Program Laboratory Testing. A laboratory program of isothermal cold-flow modeling and pilot-scale combustion testing was established to support the design and field testing activities under the tangentially fired sorbent injection demonstration program. The laboratory program drew heavily from the results of the Sorbent Injection Criteria Program discussed above.

Cold-flow isothermal testing was conducted on a 1:9 scale model of the right half of Yorktown Unit No. 2. This model is shown in Figure 9. A multi-level screening process was used to identify candidate injection configurations which were most suitable for Yorktown and which were most likely to achieve the desired SO_2 reductions.

The next laboratory activity under the demonstration program is pilot-scale combustion testing of the candidate injection configurations in the BSF. This activity is scheduled for late summer 1988. The upper furnace region of the BSF has been modified to more closely simulate Yorktown Unit No.

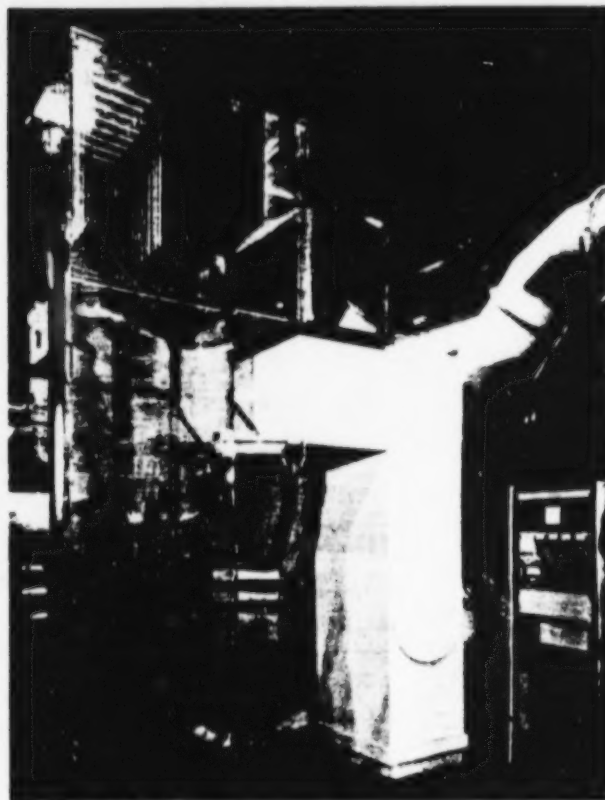


Figure 9 Cold-Flow Model of Yorktown Unit No. 2

2. Testing will be conducted with a low- NO_x firing system similar to that which will be installed at Yorktown. The coal and sorbent which will be used during the demonstration at Yorktown will be used during these tests.

The final scheduled laboratory testing activity will be to evaluate boiler and ESP performance characteristics with the demonstration coal in C-E's 1.2 MW(t) (4×10^6 Btu/hr) Fireside Performance Test Facility (FPTF). The primary objective of this activity will be to assess the impact of sorbent injection on ash deposition, erosion, and ESP performance. Testing will be conducted with and without sorbent injection. The test data will assist efforts to accurately model the expected thermal performance of Yorktown Unit No. 2, with and without sorbent injection. FPTF testing is scheduled for the fourth quarter of 1988.

Determination of Baseline Conditions

Accurate definition of boiler performance without sorbent injection is critical in determining the effectiveness of this process in controlling SO_2 , as well as in establishing the normal operating characteristics at Yorktown Unit No. 2, including fouling, ash handling and disposal requirements, and ESP performance. C-E will characterize the performance of the unit, with the existing tangential firing system, prior to installation of the sorbent injection and low- NO_x firing systems. A test of 30 days duration on the higher sulfur demonstration coal will be conducted in late 1989. Extensive emissions and boiler performance data will be acquired throughout the continuous 30-day test.

These data will establish a baseline level of boiler performance, including SO₂ and NO_x emissions, against which subsequent sorbent injection demonstration testing can be compared.

Conduct of Demonstration Program

Under this task, C-E will carry out the field demonstration portion of this program by retrofitting Yorktown Unit No. 2 with an integrated sorbent injection system, including flue gas humidification, plus firing system modifications, and operating this system continuously for 8 months.

Detailed engineering design of the sorbent injection storage, handling, and injection equipment, flue gas humidification and sorbent recycle equipment, low-NO_x firing equipment, and boiler modifications will be conducted under this task. Equipment installation and erection is scheduled for 1990. Boiler penetrations and other gas path modifications are scheduled for a planned Unit No. 2 outage during the spring of 1990.

Following an equipment start-up and optimization period, the integrated system will be operated continuously for 8 months over the normal boiler duty cycle. Extensive emissions and boiler performance data will be acquired throughout the demonstration test during four 30-day test periods. The current schedule is to test for 4 months with furnace sorbent injection alone, 2 months with furnace sorbent injection plus flue gas humidification, and 2 months with furnace sorbent injection, flue gas humidification, and injection of fresh sorbent into the ESP inlet ducts to simulate recycle. In light of the adverse impact of sorbent injection on ESP performance which was seen during testing at Edgewater, it may be necessary to modify this schedule to include flue gas humidification throughout the demonstration test.

The data obtained during this demonstration test program will be analyzed and compared against baseline data to establish the effects of sorbent injection on emissions, boiler performance, and waste disposal. Incremental costs associated with the process will be identified.

Preparation of Recommendations and Guidelines for LIMB Commercialization

C-E will evaluate the results of the Yorktown demonstration program, along with the results of other ongoing test programs (prototype testing at Richmond Power and Light, pilot-scale testing at C-E's BSF), and prepare recommendations and guidelines for the further commercialization and use of the sorbent injection process at other tangentially coal-fired boiler sites.

Site Restoration

Upon completion of the demonstration test, Yorktown Unit No. 2 and the Yorktown site will be returned to its original condition, less normal wear and tear, subject to discussions between Virginia Power and the EPA.

SUMMARY

With the advent of the acid rain issue, utilities and industry are again investigating sorbent injection as a cost-effective alternative to conventional desulfurization systems for achieving moderate levels of SO₂ removal which would be sufficient to meet SO₂ emission requirements for pre-1971 coal-burning units. This paper has described recent C-E activities in the area of furnace sorbent injection for tangentially fired boilers. Successful completion of the Yorktown demonstration program will firmly establish the viability of this process as an alternative to scrubbers for SO₂ control.

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